June 7.

The President, Dr. Ruschenberger, in the chair.

Eighteen persons present.

The following was ordered to be printed:

OBSERVATIONS UPON THE HIPPOPOTAMUS.

BY HENRY C. CHAPMAN, M. D.

On several different occasions, before and during the reign of Augustus and of his successors, Antoninus, Commodus, Heleogabalus, etc., the Hippopotamus was exhibited at Rome. Naturally one would suppose, therefore, that among the writers of those times a truthful description of this interesting animal would be found. Pliny's [1] account, however, is only a restatement of the imperfect and erroneous descriptions of Herodotus and Aristotle, with some mistakes of his own added, while those of later Latin writers like Tatius, though better than Pliny's, are still obscure and contain errors. Indeed, the Hippopotamus, as described by Herodotus [2] and Aristotle,[3] is so unlike the animal known at the present day, that either these usually most accurate and trustworthy observers could never have seen the Hippopotamus or else they must have described some other animal under that name. About the middle of the sixteenth century it is said that Belon saw the living Hippopotamus at Constantinople, but even so late as the time of Cuvier [4] the living animal had not been seen in Western Europe. The London Zoological Garden, I believe. has the credit of having been the first in modern times (during 1850) to exhibit the living Hippopotamus.

So far as I know, the first dissection of this animal was made in 1764, by Daubenton.[5] The specimen, however, being a female

[1] De animalibus, Lib. viii, cap. xxxix; Lib. ix, cap. xiv.

[2] Historia, Lib. ii, cap. lxxi.

[3] Historia Animalium, Lib. ii, cap. iv.

[4] Ossemens Fossiles, Tome deuxieme, p. 383.

[5] Histoire naturelle, &c., avec la description du Cabinet du Roi. Tome douzieme, 1764, p. 50. Supplement to Buffon.

fœtus, it was questionable how far the description would apply to the adult animal. Nothing further was added to the above account until, in 1844, Vrolik[1] described the stomach of a half-grown individual from drawings sent from the Cape of Good Hope. A few years afterwards Peters,[2] in his Travels, gives a short but valuable account of the appearance that the viscera presented in the adult animal. It will be seen, therefore, that the knowledge of the soft parts of the Hippopotamus was very limited up to quite a recent period. During 1867 there appeared the elaborate monograph of Gratiolet[3] on the anatomy of this animal, and the important observations of Crisp.[4] Gratiolet's description was derived from his dissection of the two young animals, male and female, that were born and had died in the Jardin des Plantes. Science is indebted to Dr. Alix for the publication of this important work, Gratiolet dying before its completion. This distinguished anatomist had, however, before his death, communicated to the Académie des Sciences,[5] an abstract of his researches. A third young Hippopotamus having died in Paris during the preparation of the work just referred to, Dr. Alix had a further opportunity of supplementing and confirming Gratiolet's views. Dr. Crisp's specimen was a male and about fourteen months old; it was burnt to death in the fire that destroyed the Crystal Palace in London, and was the first Hippopotamus dissected in England. Dr. Crisp[6] refers to Gratiolet's abstract in Annales des Sciences Naturelles for 1860, but does not mention that in Comptes Rendus for 1860. His observations were, therefore, uninfluenced by those of Gratiolet. In 1872, Mr. J. W. Clark[7] published the "Notes on the Visceral Anatomy of the Hippopotamus" that died in the London Garden. This animal was a female, and only a few days old.

It is well known that in addition to the ordinary Hippopotamus, there is a rarer species from the Western Coast of Africa, first

[1] Amsterdam Verhandelingen, x, 1844, p. 240; Recherches sur la Babyrussa.

[2] Reise nach Mosambique, 1852, i, p. 180.

[3] Recherches sur l'anatomie de l'Hippopotame. Paris, 1867.

[4] On some points connected with the anatomy of the Hippopotamus. Proc. of Lond. Zool. Soc., 1867, p. 601 and 689.

[5] Comptes Rendus, 1860, pp. 524, 595.

[6] Op. cit., p. 601.

[7] Proc. Zool. Soc., London, 1872, p. 185.

made known by Morton,[1] and called by him *Hippopotamus Liberiensis.* Its osteology was afterwards fully described by Prof. Leidy,[2] who showed that this species differed so much from the ordinary one that a distinct name, *Chœropsis*, was given to it, as indicating that the supposed new species was really a new genus. Prof. Leidy's views have since been thoroughly corroborated by other anatomists, particularly by Milne Edwards,[3] in his recent beautiful monograph on this animal. The only living example of the *Chœropsis Liberiensis* ever seen outside of Africa was the female specimen only three or four months old that died a few minutes after arriving at the Zoological Gardens in Dublin in 1874, and that formed the subject of a paper by Mr. Alex. Macalester.[4] Since then, within a year, the late lamented Dr. A. H. Garrod [5] communicated to the Zoological Society of London the results of his dissection of the adult male Hippopotamus that had lived twenty-eight years in their admirably conducted Garden. It will be observed from this resumé of the literature of the subject that, with one or two exceptions, the Hippopotami that have been dissected were young animals; some not more than a few days or weeks, others about a year old, and that with the exception of the *Chœropsis* examined at Dublin, they were of the ordinary kind, or the *Hippopotamus amphibius.*

While the general results of these various observations are confirmatory of each other, nevertheless, on account of the difference in the age and sex of the individuals dissected, it is still important that whenever the opportunity presents itself of examining a full or half-grown Hippopotamus the results of such dissection should be compared with those already made for the sake of confirming, supplementing, or further illustrating them. It is with this object that I bring before the Academy the results of my examinations of the female Hippopotamus which recently died in the menagerie of Mr. Adam Forepaugh, to whom I am indebted for the opportunity of dissecting it; and of the male specimen that died in New

[1] Proc. Acad. Nat. Sciences, vol. ii, p. 14; Journal, vol. i, 1849, p. 231.

[2] Journal Acad. Nat. Sci, vol. ii, 1852.

[3] Recherches sur les mammiferes.

[4] Proc. of Royal Irish Academy, 1874. The anatomy of Chœropsis Liberiensis.

[5] Trans. of Zoo. Soc. of London, 1880. On the Brain and other parts of the Hippopotamus.

York on its way to the Zoological Garden of Philadelphia. I take the occasion also of thanking Mr. Arthur E. Brown, Superintendent of the Zoological Garden where the dissections were made, for materially assisting me in the investigation.

Both the animals were examples of the ordinary species, the *Hippopotamus amphibius*, and measured about 5 feet 6 inches in length. The female was both the taller and heavier of the two. Her height at the shoulder being 28 inches and weight 550 pounds. She was probably older than the male. The condition of the skin in the female suggested the idea that it had not been sufficiently bathed during the past winter. It is well known that the health of the skin, and of the animal generally, depends upon the free use of water, either in the form of a bath, or where that is not practicable, by constant sponging, etc. With the exception of some slight inflammation of the fourth stomach and an apparent hypertrophy of the left ventricle of the heart, the organs were healthy. The male animal died from an inflammation of the stomach and intestines, the epithelium and submucous tissue in parts of the stomach being stripped off, while portions of the intestine were gangrenous. The immediate cause of death was a large well-organized clot in the heart. As the myology of *Hippopotamus* and of *Chœropsis* have been described and figured by Gratiolet[1] and Macalester[2] respectively, I will not dwell upon this part of the subject, but pass to the consideration of the internal organs.

Alimentary System, etc.—The tongue of the Hippopotamus (Pl. XI, fig. 1) is a long, flattened organ expanded and rounded off at the top rather than tapered. It measured 14 inches in length, in breadth 3½ inches at the middle and 5 inches at the top. At the back of the tongue where one finds the circumvallate papillæ in man, in place of these are seen what might be called elongated, thorny papillæ. They do not correspond to either the human filiform or fungiform papillæ. The latter were well developed. I did not notice anything peculiar about the submaxillary gland, the sublingual however was absent;[1] the parotids were present, but not very well developed, as Gratiolet states was the case in the animals examined by him. The small size of the parotids in the Hippopotamus may be due to the habit of passing so much time in the water; the necessity of the secretion not being felt,

[1] Op. cit., Planches IV to VIII.

[2] Op. cit., pages 496, 500.

[3] Op. cit., p. 384.

as is the case in fishes. According to Gratiolet,[1] it is doubtful if they were present in the very young animal.

What at once struck me, on exposing the larynx, etc., was the space (Pl. XI, fig. 1) intervening between it and the tongue, and the large size of the back of the tongue as compared with the epiglottis. Through the flexibility of this space the larynx when elevated can be thrust up into the posterior nares; this space, together with the tongue, effectually cutting off the cavity of the mouth. This can be well seen in the living animal. It is possible that this disposition of the parts may be of advantage to the Hippopotamus when sunk in the water. Under such circumstances, the nose only appearing, the air can pass into the external nares and so back directly into the larynx. Further, as the external nares are extremely flexible and close very tightly, it may be that the animal before sinking under the water can take in a considerable quantity of air into the nose and retain it there until needed, when it is then drawn into the larynx. On looking over the literature of the anatomy of the Hippopotamus, I find that Gratiolet[2] and Clark[3] are the only ones who dwell particularly upon this part of its economy. Clark gives figures of the spaces I have referred to, and points out what appears to be the probable function of the parts. The larynx and its muscles have been well described by Gratiolet,[4] Crisp[5] and Clark.[6] It would be superfluous therefore for me to dwell upon them. I will, however, call attention in this connection to the fact of the epiglottis (Plate XI, figs. 1 and 2 *e*) being small as compared with the larynx (Plate XI, fig. 2), the former measuring 2½ inches in length, and 2 inches wide, the latter being 6½ inches long and 6½ in circumference, and that the nares, epiglottis, etc., of the Hippopotamus reminded me rather of those of the Manatee than of those of the Cetacea. The vocal cords were situated obliquely, the anterior ends being lowermost; they measure 2 inches in length and ½ inch in depth. There was nothing peculiar about the lungs; they were not divided into lobes or subdivided into lobules recognizable by the naked eye, as described by Gratiolet.[7]

The stomach in the Hippopotamus is subdivided into four distinct

[1] Op. cit., p. 384.
[2] Op. cit., p. 375.
[3] Op. cit., p. 188.
[4] Op. cit., p. 305.
[5] Op. cit., p. 608.
[6] Compare Gratiolet, op. cit., p. 368.
[7] Op. cit., p. 374.

compartments, *b*, *c*, *d* and *e* (Plate XII); the first, *b*, however, not being so apparent externally as the other three (shown in Plate XI, fig. 3). The œsophagus. *a* (Plate XII), opens freely into the compartment *b*, which is situated posteriorly, and which might be easily overlooked unless opened. I propose calling this compartment the first stomach, as the food can pass from the œsophagus into it without necessarily passing into either of the other two stomachs, *c* and *d*, whereas the food must pass through a small part at least of *b* in order to get into *c* or *d*. This is due to a peculiar disposition at the entrance of the stomachs *c* and *d* (Plate XIII). At this point the lining membrane is raised up into two valvular folds, *g* and *h* (Pl. XIII), of which the former is the best developed. The fold *g* almost divides the second stomach into two parts. These folds are 10 and 4 inches in length respectively, and about the $\frac{1}{8}$ of an inch in breadth, and contain muscular fibres. When these folds are approximated the œsophagus, *a*, and first stomach, *b*, are completely shut off from *c* and *d*. When, however, the valvular folds are separated, then the food can pass from the œsophagus, *a*, or from stomach, *b*, over the edges of the folds, *g* and *h*, into either the stomachs, *c* or *d*. As the compartment *d* passes into *e*, which is continuous with the intestine, *f*, it appears to me that the two compartments may be appropriately called the third and fourth stomachs, in which case *c* would be the second one.

From a simple inspection of the stomachs of the Hippopotamus, one would be disposed to conclude that the animal was a ruminant. As the act of rumination, however, has never been observed in the Hippopotamus, either in captivity or in the wild state, so far as is known, the inference must be that the food passes either directly from the œsophagus into the second or third stomachs, as is probably the case with liquids, or into the first stomach, and then indirectly into the second or third, when more solid articles are introduced.

The four stomachs differ considerably in size, the third, *d*, being by far the largest; it measured from right to left 27 inches, as seen in situ in Pl. XII; it overlaps, when viewed from the anterior surface, the second and fourth stomachs, *c* and *e*, and, to a great extent conceals the first stomach, *b*, especially when the latter is empty. The first stomach, *b*, measured 15 inches from right to left, and is so closely united to the third one, *d*, that externally the two look like one when empty, and their distinctness does not become evident until they are forcibly separated and opened. The first stomach is also connected laterally with the third and fourth ones. These are about the same length, 7 inches, measured from right to left. The third stomach communicated with the fourth by a narrow aperture, which measured 3 inches in diameter. In situ the second stomach was situated in the left hypochondriac region; the fourth stomach on the right; the third stomach lying between the third and fourth and in the same plane, and in front and partially concealing the first stomach.

The difference in the four stomachs of the Hippopotamus viewed internally are even more marked than those observed externally. The smooth mucous membrane of the œsophagus contrasts strongly with that of the first stomach, in which the mucous membrane exhibits parallel folds or ridges. In the second stomach the ridges are seen, but here they consist of rows of villi, averaging the $\frac{1}{8}$ of an inch in height; the villi are not so closely set on the rows but that they can be readily distinguished. The villi in the third stomach, however, are densely packed and smaller than those of the second stomach. In addition the mucous membrane is thrown into eight large (the seventh divided into two) folds that run at right angles to the long axis of the stomach. The mucous membrane of the fourth stomach differed from that of the others in being the only one containing the gastric glands; according to Dr. Hunt, these measure in length $\frac{1}{12}$ of an inch, in breadth $\frac{1}{750}$ of an inch. The food did not seem to be digested to any extent in the first three stomachs, but lay as a sodden mass. In the fourth stomach, however, the food was softened, and its general appearance differed from that of the other stomachs. As the animal died shortly after eating, digestion had not been going on any length of time, so that any great change in the food could not have taken place. In the case of the male, the fourth stomach had been affected by disease and the food appeared almost unchanged. The small intestine in the female measured 70 feet, the large intestine 11 feet. There were no valvulæ conniventes in the small intestine but the mucous membrane was villous and exhibited the Lieberkühnian follicle and the Peyer's patches in the lower two-thirds. There was no very sharp line of demarkation between the small and large intestines, the beginning of the latter being indicated by a slight enlargement. A small transverse fold was the only indication of an ileocæcal valve. As might have been expected on account of the large and complex stomach, there was no well defined cæcum. It is an interesting fact, however, that the peculiar glandular-like structure in the cæcal end of the colon of the Giraffe first described by Cobbold, should be present in the Hippopotamus. There was nothing very peculiar about the pancreas or the spleen. The duct of the former pierced the duodenum separately from the ductus choledochus. The latter was closely bound to the greater curvature of the stomach by a fold of peritoneum. The liver was a quadrilateral mass not subdivided to any extent into lobes. The gall bladder was absent in the female; in the male, however, it was present and measured 6 inches long.

On comparing my observations with those of the anatomists already referred to, I find, that while some of the descriptions accord very well with mine, others differ considerably. Thus Daubenton's description is very good, especially when it is remembered that it is based upon the examination of a fœtus. His[1] figures give a very good idea of the relations of the four stomachs when they are separated from each other by division of their connecting bands. Peters'[2] and Vrolik's[3] accounts are very fair. Unfortunately, however, no figures are given. On the other hand, I cannot say that the figure given by Crisp[4] of the stomachs illustrate the specimens examined by me. His descriptions, however, of the colic gland, spleen, liver and pancreas accord very well with my observations. Clark[5] gives four figures, illustrating the stomach described by him, that by Gratiolet, and of one preserved in the Museum of the Royal College of Surgeons. The figure of the latter gives a much better idea of the stomach examined by me than either that of Clark's or Gratiolet's. Garrod[6] states that "he could find no confirmation of the peculiar position of the different parts described by Mr. J. W. Clark in his specimen." Possibly these differences observed in the stomach may be due to age, sex, to the extent to which the different stomachs had been separated, or to the amount of food that they contained, etc. As all of these conditions will influence greatly the form of the organ, it need not occasion surprise that I find the accounts

[1] Op. cit., figs. 1 and 2, Pl. IV.

[2] Op. cit., p. 180.

[3] Op. cit., p. 240.

[4] Op. cit., fig. 3, p. 604.

[5] Op. cit., figs. 4, 5, 6, 7, p. 190.

[6] Op. cit., p. 16.

somewhat discordant, without, however, intending to throw discredit upon any of them.

A Peccary having died at the Zoological Garden the same day that the Hippopotamus arrived there, a favorable opportunity presented itself of comparing the stomachs of the two animals. While externally the stomach of the Peccary is not subdivided to any great extent, internally through the elevation of the mucous membrane into two ridges, three compartments, cardiac, middle and pyloric, may be distinguished. The cardiac portion further subdivided at its termination into two blind pouches, opens into the middle division of the stomach; the latter receives the œsophagus and communicates with the pyloric part. Conceive the ridges and the cardiac pouches in the stomach of the Peccary greatly enlarged and we would have the stomach of a small Hippopotamus. On the other hand, diminish the first two stomachs of the Hippopotamus to mere blind pouches, at the same time increasing the constriction between the third and fourth ones and we have, without any stretching of the imagination, the stomach of the Manatee. Beginning with the Pig the transition from that form of the stomach through the Babyrussa[1] to that of the Peccary is an easy one. The latter again, leads to the Hippopotamus, which in turn anticipates on the one hand the Manatee and on the other the Ruminant type.

Vascular System.—The circulation of the blood in the Hippopotamus was first studied by Gratiolet. The result of his careful investigation was the subject of a special communication to the Academy of Sciences, which appeared in the *Comptes Rendus*,[2] several years before the publication of his more general work by Dr. Alix. A good account of the heart is also given by Crisp.[3] With the exception of the above accounts, little or no attention seems to have been given to the study of the circulation by those anatomists who have dissected the common variety of Hippopotamus, Daubenton[4] devoting merely a few lines to the heart, while the later writers do not mention the circulation at all. Macalester[5] mentions one or two peculiarities about the blood-vessels in the Chœropsis. Although I have nothing particularly to add to Gratiolet's excellent description, inasmuch as the subject of his

[1] Vrolik, op. cit., p. 240. [2] Tome li, p. 524, 1860, 1867.

[3] Op. cit., p. 609. [4] Op. cit., p. 57. [5] Op. cit., p. 495.

dissection was only a day old, it was important that the heart and blood-vessels in a more fully developed animal should be examined with reference to determining whether the circulation was in any way modified by age.

On opening the thorax of the animal it appeared to me that in both sexes the heart was large in proportion to the size of the animals. This is in a great measure due to the thickness of the walls of the left ventricle. In the female Hippopotamus, which was the first examined, I suspected this might be due to hypertrophy, but finding it to be the case in the male also, perhaps this is normal. The heart, in an empty condition, measured, from base to apex, 9 inches, and in circumference 14 inches. The wall of the left ventricle measured 1 inch in thickness, that of the right $\frac{1}{5}$ of an inch. According to Gratiolet,[1] the heart in the young Hippopotamus terminates in two points, the ventricles being separated by a little groove, reminding one of the form of the heart in the Manatee and the Dugong. There was no indication of this groove in either of the Hippopotami examined by me. With the exception of the absence of the corpora arantii on the semilunar valves of the pulmonary artery and their very slight development in those of the aorta I did not notice anything peculiar about the interior of the heart. The aorta gave off the coronary arteries first, which were very large and then an innominate and the left subclavian. The innominate divided into the right subclavian and a trunk which bifurcated into the two common carotids. The external carotid as well as the ascending cervical and occipital arteries were all rather slender vessels in proportion to the size of the head and neck. The external carotid artery was very much larger than the internal. A peculiarity about the external carotid artery of the Hippopotamus first described by Gratiolet,[2] I noticed in both the male and the female animals, the fact of the vessel in its course towards the head passing between the hyoid bone and the digastric and stylo-hyoid muscles in such a manner that when the hyoid is elevated the vessel is compressed against the bone by these muscles. The effect of this disposition is that the blood is cut off to a great extent from the brain and head when the animal sinks under water, the hyoid being elevated at such times. Gratiolet

[1] Recherches, p. 358, and Planche III.

[2] Op. cit., p. 354.

having shown that the external carotid through the sphenoidal branch of its internal maxillary communicates with the carotid rete mirabile, this sphenoidal branch in the Hippopotamus is as large as the internal carotid and plays the part of an "anterior internal carotid." In this connection I may say that it appeared to me that the elevation of the hyoid bone would compress the internal carotid artery as well as the external, the common carotid bifurcating between the digastric muscle and the hyoid bone in my specimens. The return of the venous blood to the heart from the head, however, was not impeded in any way, the jugular veins lying to the outside of the muscles which compressed the carotid arteries. The superior mesenteric artery came off the aorta in common with the cœliac, the inferior mesenteric separately. The common trunk of the external and internal iliacs was short. I did not notice any rete mirabile in the arteries of the body or extremities. In this respect the venous system, however, differed very considerably from the arterial. I was struck with the large size of the cutaneous and subcutaneous veins and of the many anastomoses between them, especially in the extremities, where numerous rete exist. Another peculiarity about the venous system in the Hippopotamus is the difference between the superior and inferior vena cavæ. The superior being very large and readily transmitting the blood to the heart, whereas the inferior cava, at least that part of it above the diaphragm, is rather small. According to Macalester,[1] in *Chœropsis* a left superior vena cava is partly represented by a small vein. As Gratiolet first showed, there is found in the walls of the vena cava above the diaphragm a circular band of muscular fibres which in contracting will entirely or partially constrict the vessel. The effect of such action is that the blood in the inferior cava is prevented returning to the heart. The circular muscular band in the Hippopotami examined by me was $\frac{1}{2}$ an inch broad. Such a disposition of the vena cava is also seen in the Seal[2] and in some other mammals which habitually remain under water for a certain length of time.[3] Below the diaphragm the vena cava was very much dilated, while the openings into it of the hepatic veins were enormous. It will be seen from the above that while the venous blood readily returns from

[1] Op. cit., p. 495.

[2] Burrow, Muller's Archiv, 1838.

[3] Milne Edwards' Physiologie, Tome iii, p. 594.

the brain and cord and upper extremities to the heart, that from the viscera and lower extremities can be entirely cut off from it, welling back into the dilated cava and cutaneous veins, while congestion of the brain can be prevented when the animal sinks under water by the obliteration of the carotid arteries. In this way paralysis of the respiratory centres of the brain and cord through congestion is prevented, while the demand for fresh air is diminished, so much blood being retained in the viscera and lower extremities and so diverted from the lungs. These peculiarities in the vascular system of the Hippopotamus—taken together with the disposition of the nares, larynx, etc., already referred to, through which the air can be retained—accounts, according to Gratiolet,[1] for the Hippopotamus being able to remain under water for so long a time, from fifteen to even forty minutes.

Bert,[2] while admitting the force of Gratiolet's reasoning, attributes the power that many animals have of resisting for a long time asphyxia, however produced, rather to the relative richness of blood that is contained in their bodies; the blood serving as a storehouse or magazine for oxygen which can be drawn upon when needed. For example, Bert has shown that the blood of the duck is richer than that of the chicken, and explains in this way that the duck will live longer than the chicken, when both are asphyxiated either by submersion in water or by ligation of the trachea. It seems to me, however, that the great quantity of blood present in those mammals that are in the habit of remaining under the water any length of time is an important element in the question. In opening several sea-lions, *Zalophus Gillespii*, that have died at the Zoological Garden, and different Cetacea, I have been always impressed with the enormous quantity of blood that literally ran out of their bodies. In presenting a specimen of a Dolphin, *Delphinus*, to the Academy, I called attention[3] to the vast rete mirabile formed by the intercostal arteries constituting the intercostal gland of the older anatomists, and which is usually regarded as a reservoir of arterialized oxygenated blood, to be drawn upon according to the needs of the animal. If the blood of the seals and cetaceans proves to be relatively richer than that of other mammals,

[1] Recherches, p. 363.

[2] Physiologie comparie de la Respiration, p. 543.

[3] Proceedings of Academy, 1873, p. 279.

it would show that both the quality of the blood, as well as the quantity, is important in enabling the animal to resist asphyxia. Not only was the quantity of blood in the Hippopotamus very great but the color in the arteries was very bright, more so than is usual in mammalian blood. Further I found the blood corpuscles measured only the $\frac{1}{7500}$ of an inch in diameter, or more strictly the $\frac{1}{300}$ of a millimetre—a Nachet eye-piece micrometer being used. The blood of the Hippopotamus should be therefore very rich in oxygen, as a corpuscle subdivided into a number of small ones would expose a larger absorbing surface to the oxygen respired than if undivided. This view is confirmatory of that of Bert, just referred to. It must be admitted, however, that according to the high authority of Gulliver, the blood corpuscle measures the $\frac{1}{3429}$ of an inch in the Hippopotamus. The fact of the Hippopotamus being able to remain under water would seem, therefore, to depend upon the peculiarities of its vascular and respiratory systems, and the great quantity and rich quality of its blood, the structural relations being as important as the chemical.

Genito-Urinary Apparatus.—In the different accounts of the Hippopotamus that I have referred to, with the exception of that of Gratiolet and of Clark, little or nothing is said of the genito-urinary organs. Daubenton[1] devotes a few lines to the description of the uterus and vagina, but his specimen, it will be remembered, was only a fœtus. Peters[2] merely alludes to the mammæ, the penis, etc. In Crisp's[3] specimen, which was a male, the parts were destroyed to such an extent as rendered detailed dissection impossible. The account in Gratiolet's[4] work is really, I presume, due to Dr. Alix, as that anatomist tells us in the preface,[5] the death of a young Hippopotamus born at the Jardin des Plantes a few days previously, gave him the opportunity of adding some details to the dissections left by Gratiolet. Alix's description of the parts, which is an account of both sexes, is excellent, but unfortunately is unaccompanied by any illustrations. Clark's[6] figure of the uterus and vagina is imperfect, but his description is very clear. It is to be regretted that Garrod[7] says nothing of the genito-urinary organs of the male animal examined by him. It

[1] Op. cit , p. 58. [2] Op. cit., p. 181. [3] Op. cit., 608.

[4] Op. cit., p. 396. [5] Op. cit., p. vi. [6] Op. cit., p. 195.

[7] Op. cit.

will be seen from the above that the genito-urinary apparatus in the male Hippopotamus have not been figured, and that of the female only imperfectly so, while the description of Alix is based on very young animals, and that of Clark is limited to the female sex. I trust that the following brief description of the parts as I found them in the male and female, with the accompanying figures will sufficiently illustrate what is wanting in the accounts hitherto given of the animal.

Genito-Urinary Organs in Male.—The kidneys, *k* (Plate XIV), measured five inches in length and were distinctly lobulated. About ten of these lobules could be counted on each face. The ureters were 7 inches in length, and opened into the bladder at the angles of the trigonum vesicæ. The bladder, *b*, from the highest point to the verumontanum in the middle line measured 9 inches. There was no sign of a prostate gland or utriculus. On each side, however, of the middle line below the verumontanum a number of little follicles could be observed. The Cowperian glands, *c*, on the other hand, are very large, being almost an inch in diameter; the main duct was well developed and opened into the urethra an inch below the gland. A considerable amount of a viscous humor could be squeezed out of the gland and duct. The muscular fibres covering the gland no doubt produce this effect in contracting. The distance from the verumontanum to the orifices of the Cowper's ducts measured four inches. The orifices of the ducts were concealed by a little fold of mucous membrane. Under this fold the membrane was thrown into delicate transverse ridges. The mucous membrane of the membranous portion of the urethra was thrown into longitudinal folds. The urethra from the openings of Cowper's ducts to its termination in the glans measured 12 inches. There was nothing exceptional in reference to the corpus spongiosum or the corpora cavernosa. The penis measured in circumference 2 inches. The ischio cavernous and bulbo urethral muscles were well developed. The symmetrically disposed retractor muscles, etc., of the penis arising from the posterior surface of the rectum pass to the bulbous portion of the urethra, where, becoming tendinous, they are continued side by side to the base of the glans into which they are inserted. The glans itself measured in circumference $5\frac{1}{2}$ inches, and when everted presents a very peculiar appearance, it being then thrown into a rosette which consists of folds arranged somewhat like the leaves of a book. The testicles, *t*, were found in the inguinal canal, midway between the internal and external abdominal rings. There was a free communication between the cavity of the peritoneum and that of the tunica vaginalis testis. The cremaster muscle was well developed, and arose, as usual, from the internal oblique and transversalis muscles. The testicle itself measured 2½ inches. The vas deferens, *v*, measured 18 inches from the epididymis to the point where it is joined by the duct of the seminal vesicle. The latter was about an inch in length, but not much developed. The ejaculatory ducts open into the urethra at the verumontanum.

Genito-Urinary Organs in Female.—The ovary, *o* (Plate XV), in the Hippopotamus is elongated and flattened, measuring an inch in length and ⅜ of an inch in breadth. The Fallopian tube, *f*, 8 inches long and ⅛ of an inch wide, pursues quite a flexuous course towards the cornua of the uterus, *cu*, into which it opens by a very small aperture. The pavilion, *p*, while not fringed, consists of a series of folds radiating from the central opening. The latter readily admitted a bristle. The cornua of the uterus, *cu*, measured 6½ inches in length and ⅞ of an inch in breadth. For the last two inches of their course the cornua run alongside of each other, and are apparently fused together, though internally they are seen to be still quite distinct. Finally, each cornu opens by a wide mouth into a common cavity, which probably represents the body of the uterus. While the mucous membrane of the cornua is thrown into longitudinal folds, that of the body of the uterus is smooth. What is usually regarded as uterus is very small, measuring only ½ an inch in length and 1¼ inches in width. It appears to me, however, that this space represents only a part of the uterus; the body and that which has been heretofore described as vagina, is really an elongated cervix uteri; this measures 6 inches in length and 1 inch in width. Its mucous membrane was elevated into seventeen folds, *c*, which are situated transversely to the long axis of the vagina, and which resemble valvulæ conniventes. These folds, on an average, were ⅜ of an inch in breadth and ⅜ inch in height, and are subdivided by indentations. Every other fold, however, alternates in reference to the part where it was most developed. Thus, the first, third, fifth folds, etc., were thickest in the middle, fading away at the sides into the walls of the vagina, whereas the second, fourth and sixth folds, etc., were thickest at the sides of the vagina, fading away towards the middle.

These folds are disposed in rather a spiral manner, and are so closely set together and developed that the cavity of the tube is almost obliterated. It is difficult, indeed, to conceive how the penis can introduce itself if this is the vagina, the rugosities being capable of offering great resistance. The folds, however, gradually fade away, and in the lower four inches of the genital tube the mucous membrane is smooth or slightly folded longitudinally. It is this part of the tube which appears to me is the vagina. It opens into the genito-urinary vestibule by a distinct aperture, through which a probe was passed without difficulty. According to Gratiolet,[1] the vagina was imperforate. The female urethra, *b*, is about an inch long, and is closely connected with the lower part of the vagina, the openings of the two tubes into the genito-urinary vestibule being situated almost next to each other. Just in front of the opening of the vagina a ridge is seen, and on either side of this ridge there are two small sinuses in which the orifices of the vulvar vaginal glands open. Externally, the vulva appears as a circular fleshy mass, 14 inches in circumference, surrounding and leading into the genito-urinary vestibule. There is no appearance of external or internal labia, and a perinæum can hardly be said to exist, the rectum lying directly against the vulva. Within the vestibule there is quite a large sinus, *s* (next to the rectum). There was nothing particularly noticeable about the clitoris, *cl*, except that the prepuce was very well developed.

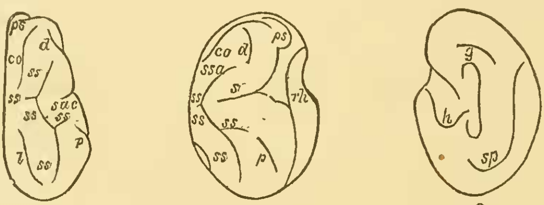
The female generative apparatus of the Hippopotamus is in every respect essentially like that of the Peccary, the only difference being in the relative size of what I have described as the body and neck of the uterus. The body of the uterus in the Peccary being relatively larger than the cervix. The peculiar disposition of the mucous membrane in folds is seen in the cervix of both animals. It is with some diffidence that I have ventured to consider as cervix the part of the genital tube usually described as vagina, for anatomists, even in the Peccary, consider the rugose portion of the tube to be the vagina. Clark[2] seems, however, to have the same opinion as expressed by me, as to the homology of the parts. The two teats were situated in the inguinal region, and although the mammary gland was but little developed externally, on section the milk-ducts could be easily recognized.

[1] Op. cit., p. 401.

[2] Compare op. cit., p. 195.

Brain.—When the study of the structure of an animal is limited to the investigation of its adult condition, without any reference to its mode of development or regard to its natural affinities with closely allied or even remote species, much will be found obscure, or even entirely unintelligible in its organization. The study of the brain is no exception to this general rule. Comparative anatomy and embryology are, indeed, the lamps which throw light upon the darkness of cerebral structure. Taking advantage of the methods cultivated with such success by Owen,[1] Leuret[2] and Gratiolet, Kreug,[3] etc., let us begin our study of the brain of the Hippopotamus by first considering, as suggested by Garrod,[4] so far as is known, the general type of the artiodactyle brain, and then ascertaining the amount of deviation from the type exhibited in the brain of the different genera. Studied in this way, the brain of the Hippopotamus will prove far more interesting and instructive than if merely described topographically.

According to Kreug the simplest kind of ungulate brain is to



1 2 3

be seen in the embryo of the Sheep, *Ovis aries*. Figs. 1, 2, 3, give diagrammatically surface, side and mesial views of the hemisphere of the same. On looking at the surface view (fig. 1), there will be observed to the right of the great longitudinal fissure the coronal fissure, *co*, anteriorly, and the lateral, *l*, posteriorly, and towards the side the supra-sylvian, *ss*, fissure with its anterior, ascending, descending, and posterior branches. In addition to these fissures may be seen upon the side view (fig. 2), the sylvian fissure, *sac*, running transversely into the rhinal fissures, *rh*, the diagonal, *d*, and the postica, *p*. The calloso marginal, *sp*,

[1] Com. Anat. of Vertebrates, vol. iii, p. 115.

[2] Anatomie Comparée du Système Nerveux.

[3] Zeit. für wiss. Zoologie, Leipzig, 1878. Band 31.

[4] Op. cit., p. 12.

genial, *g*, and hippocampal, *h*, are seen on the mesial surface (fig. 3). Let us suppose, now, that that the calloso marginal from the mesial surface and the ascending branch of the supra-sylvian blend with the coronal and that at the same time, while the descending branch of the supra-sylvian lengthens, the posterior limit shortens, we shall transform the typical ungulate brain into that of the Pig, *Sus scrofa*. On the other hand, should the posterior branch of the supra-sylvian lengthen while the descending branch shortens, the result will be the brain of the Cotylophora. The Peccary, *Dicotyles*, differs from the Pig in that the calloso marginal only joins the coronal, and that often at least, the descending branch of the supra-sylvian is wanting. In most of the Cervidæ the ascending limit of the supra-sylvian runs into coronal. From this brief resumé it will be seen that fundamentally the brain is constructed on the same pattern in the Pig, Peccary, Sheep, Camel, Giraffe, Deer, etc.

Let us now try to show that the brain of the Hippopotamus does not essentially differ from the typical ungulate brain to a greater extent than that of the animals just referred to. The most striking feature of the brain of the Hippopotamus, viewed from its upper surface, is the deep fissure, *l co* (Pl. XVI), that runs from the posterior to the anterior part of the brain, and rather in an oblique direction, being situated nearer the great longitudinal fissure anteriorly than posteriorly. This fissure serves to divide the upper surface of the hemisphere into two parts, very much as the interparietal fissure does in man; compared with the type of the ungulate brain, this fissure is evidently due, as suggested by Garrod,[1] to the lateral and coronal fissures running into each other, which I find they almost do in the Camel, Giraffe, Deer and Ox. On the right side of the Hippopotamus' brain examined by me, this fissure runs farther forward than on the left. In the ungulate brain there are usually found between the lateral fissure, that is, the posterior part of the fissure just described, and the great longitudinal fissure, one or two secondary longitudinal fissures. On the left side of the brain in the Hippopotamus a secondary longitudinal fissure may be seen, extending forward to about the usual extent, but on the right side this, *m l* (Pl. XVI), runs forward anteriorly until it passes between the coronal and the great longitudinal fissures. In this respect my specimen

[1] Op. cit., p. 15.

differs from that figured by Garrod.[1] In the brains of the Llama and Giraffe these secondary longitudinal fissures are often found both anteriorly and posteriorly, and are almost continuous with each other; on the other hand, in the brain of the Peccary used by me for comparison, the secondary longitudinal fissure, usually found posteriorly, is absent. The sylvian fissure in my Hippopotamus is quite evident, and within it I noticed a rudimentary island of Reil. This fissure on the right side differs from that described by Garrod, in that it is quite distinct from the Rhinal fissure, there is, however, posteriorly a little connecting branch between the two. I identified, as Garrod,[2] on the left side of the brain the supra-sylvian fissure with its branches, but these were not well matched on the right side. On the mesial surface the calloso marginal sent up a fissure which nearly reached the latiro coronal and terminated in the genial.

As is usually the case in the artiodactyle, there was a secondary fissure between the corpus callosum and the calloso marginal. The minor convolutions of the brain of the Hippopotamus are not very numerous. Indeed, the brain is much less convulated than those of the Giraffe, Llama, or even the Peccary, used by me for comparison; in the general form of its hemispheres the brain of the Hippopotamus resembled that of the Giraffe; the cerebellum, however, differed from that of the Giraffe, Peccary, and other artiodactyles in that its largest diameter was transverse, whereas, in the animals just mentioned, the largest diameter of the cerebellum was antero posterior; the latter, however, seems to be the case in the young Hippopotamus, at least judging from Gratiolet's [3] figure. In the adult the cerebellum resembled more that of the Manatee than that of the Artiodactyle. As the description and figures of the brain of the Hippopotamus given by Gratiolet [4] and Garrod [5] are limited to the surface, it appeared to me very desirable that the interior of the ventricle should be exposed and figured. On making the section, I found a septum lucidum. The lateral ventricle was very large, recalling to my mind that of the Manatee, dissected by me some years since. According to Macalester's figure the ventricle is also large in *Chœropsis*. The general

[1] Op. cit., Plate III, fig. 1.

[2] Op. cit., Plate IV, fig. 3.

[3] Op. cit., fig. 2, Pl. XII.

[4] Op. cit., p. 317, Pl. XII.

[5] Op. cit., p. 14, figs. 1, 2, Pl. 3; figs. 1, 2, 3, Pl. 4.

appearance and size of the corpus striatum, *s*, tænia, thalamus opticus, *o*, and hippocampus major, when compared side by side with the corresponding parts of the Manatee, resembled these more than they did those of the Giraffe, Llama, Peccary, etc. Of the corpora quadrigemina in the Hippopotamus, the testes, *t*, were broader than the nates, *n*, and less rounded in shape.[1]

If the above description of the brain of the Hippopotamus be correct, it follows that the general form of its hemispheres, the arrangement of its fissures, etc., deviate but little from the typical ungulate brain, while the capaciousness of its ventricles, the form of its basal ganglia, and the cerebellum, resemble rather those of the brain of the Manatee.

Sweat Glands.—As is well known, when the Hippopotamus comes out of the water there exudes from the skin a pinkish, reddish secretion, which quickly dries up and does not reappear until the animal comes out of the water again. This secretion has probably given rise to the name blood-sweating Behemoth, by which the Hippopotamus is often known among showmen. This secretion was first examined by Tomes,[2] who stated that it consisted of a transparent fluid containing colorless and red-colored corpuscles, the color of the secretion being due to the solution of the latter. Crisp[3] examined and figured the glands supposed to produce this secretion. It will be remembered that his specimen was burnt to death, and it was to be expected, therefore, that the skin was affected. For this reason I requested that admirable microscopist, Dr. J. Gibbons Hunt, to examine the skin of my Hippopotamus, and I give his result in his own words:

"I put in a camera lucida sketch of the blood-gland (fig. 4) of the Hippopotamus magnified 25 diameters. It has no limiting membrane, but bioplasts or nuclei of the usual apparent form make up the entire gland. In the centre these gland-cells are loosely arranged, thus allowing the contents to escape, perhaps, like common sweat glands do, in which, similarly, there is no external or internal membrane."

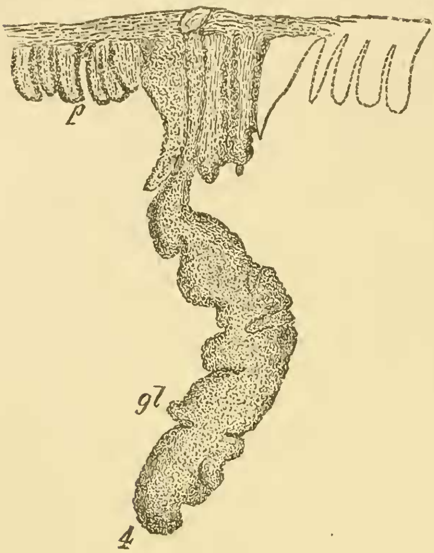
The contents of the gland-cells loosely arranged in the centre are probably the corpuscle, the solution of which, according to

[1] Peters gives in Monatsberichte of Berlin Acad., 1854, a brief description of the brain of the Hippopotamus, but unfortunately not illustrated.

[2] Proc. Zool. Soc. of London, 1850.

[3] Op. cit., p. 602.

Tomes, gives rise to the color. The length of the blood gland measured $\frac{1}{15}$ of an inch, in width the $\frac{1}{45}$ of an inch, the length of the duct $\frac{1}{30}$ of an inch. In many parts of the skin these glands are absent, and when present are situated about the $\frac{1}{10}$ of an inch below the surface.



A most striking feature in the skin of the Hippopotamus is the great development of the fibrous tissue of the corium. This is disposed in great bands, which are so interwoven with each other as to give the appearance of a fabric.

Reflections.—In concluding these observations, it may not appear superfluous to briefly consider what appears to me to be the natural affinities of the Hippopotamus with the Ungulata or other mammalia. In observing the Manatee that lived for several months in the Philadelphia Zoological Garden, the manner in which it rose to the surface of the water to breathe reminded me often of the Hippopotami that I watched in the Zoological Garden of London and the Jardin des Plantes in Paris. The slow way in which the animals rise to the surface, the motionless pose of the almost sunken body, the nostrils often just appearing at the surface, etc., are very much alike in both animals. In speaking of the alimentary canal, I called attention to the stomach of the Manatee representing the stomach of the Hippopotamus in an atrophied condition, while, on the other hand, the stomach of the Hippopotamus is intermediate between the Peccary and the Ruminants. As regards the heart, it will be remembered, that in the young Hippopotamus, at least, it is bifid, resembling in this respect that of the Manatee. The female generative apparatus of the Peccary and Hippopotamus are almost identical. Again, the sexual vesicles are found in both Hippopotamus and Manatee.

While the placenta does not appear to me to have the importance attached to it by some authors as a guide in determining the affinities of animals, it is proper to mention in this connection that according to Milne Edwards[1] and Garrod[2] the placenta of the Hippopotamus is diffuse and appears to be non-deciduous, and such is the case, according to Harting,[3] in the Dugong,[4] and therefore in the Manatee, probably, for as a matter of fact the placentation of the Manatee is unknown.

While the brain of the Hippopotamus appears to be a modification of a type common to the Pig, Peccary, Sheep, Ox, Giraffe, etc., it has also, it seems to me, affinities with that of the Manatee. In a word, then, beginning with the Pig, we pass by an easy transition to the Peccary, which leads to the Hippopotamus, and thence, in diverging lines, to the Ruminantia on the one hand, and the Manatee on the other. Paleontologists have not discovered a form which bridges over the gap between the Hippopotamus and the Manatee, but it will be remembered that certain fossil bones, considered by Cuvier[5] to have belonged to an extinct species of Hippopotamus, *H. medius*, are regarded by Gervais[6] as the remains of the *Halitherium fossile*, an extinct Sirenean, of which order the Manatee is a living representative. According to Prof. Owen,[7] the molar teeth also, both in the *Halitherium*, and the *Felsinotherium*,[8] another Sirenean, are constructed on the same pattern

[1] Physiologie, Tome 9, p. 56.

[2] Proceed. Zool. Soc., 1872, p. 821.

[3] Tijdschrift der Nederlandsche Dierkundige Vereenigung, Deel iv, 1879, p. 1.

[4] Dr. Hartung, in his very valuable paper on the placenta of the Dugong, just referred to, describes and figures bodies attached to the blood-vessels resembling. apparently, very much those of the placenta of the Elephant. His figure (7) shows that the cavity of the vessel communicates with that of the body attached to it. Dr. Harting inquires whether such is the case in the Elephant. I will state in reply, that neither Dr. J. Gibbons Hunt nor myself found any such continuity between the vessel and body in the placenta of the Elephant. These oval bodies in the Elephant are not sacs or cavities, the little branches from the main vessel only ramify through their substance. There seems, then, to be an essential difference between the oval bodies in the placenta of the Elephant and in that of the Dugong.

[5] Ossemens Fossiles, II, p. 492.

[6] Paleontologie Francaise, p. 143.

[7] Geological Magazine, 1875, p. 423.

[8] De Zigno, Sopra un nuovo suienio fossile. Reale Acad. dei Lincei, 1877–78.

as those of the Hippopotamus. It is proper to mention, however, that the same distinguished observer considers the teeth of the Manatee and the *Prorastomus*, another extinct Sirenean, to be rather allied to those of the Tapir and *Lophiodon*, but this qualification does not really invalidate the supposed affinities between the Sirenea and the Hippopotamus. For the Artiodactyla and Perisodactyla are probably offshoots of a common stock, and hence we may expect to find in these two groups certain characters common to both, inherited from their Lophiodon and Coryphiodon-like ancestors. The affinities of the teeth of the Manatee with those of the Tapir—the first an embryonic Artiodactyle, the second a generalized Perisodactyle—would be examples of the above view. I do not mean to imply that the Manatee has necessarily descended directly from the Hippopotamus, though extinct intermediate forms may in the future show this to be so, for possibly they may be the descendants of a common ancestor. To many such speculations may appear mere waste of time, we being unable, from the nature of the case, to experimentally prove or disprove the truth of the hypothesis advanced. It seems to me, however, that the only explanation of the structure of the living forms and of the petrified remains of the animals referred to in these observations is the hypothesis of there being some generic connection between them.